ON THE CLARIFICATION OF LARVAL TUNA IDENTIFICATION PARTICULARLY IN THE GENUS *Thunnus*

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ABSTRACT

A Larval Tuna Identification Workshop was held at the Bureau of Commercial Fisheries Biological Laboratory (now the National Marine Fisheries Service, Southwest Fisheries Center), Honolulu, Hawaii, on March 2-6, 1970, to resolve conflicting views on the identification of larvae of *Thunnus alalunga* and *T. albacares* and to clarify the status of larval identification of other *Thunnus* species.

The identification of *T. alalunga* (Yabe and Ueyanagi, 1962), *T. albacares* (Matsumoto, 1958), *T. obesus* (Matsumoto, 1962), and *T. thynnus* (Yabe, Ueyanagi, and Watanabe, 1966) was agreed upon as correct, except that the description of *T. albacares* should include the appearance of black pigmentation at the tip of the lower jaw when the larva attains a length of about 4.5 mm SL and that the lower size limit of reliable identification of *T. alalunga* be set at about 4.5 mm SL until further studies indicate more precisely whether the black pigmentation at the tip of the lower jaw in *T. albacares* appears earlier. There was no difference in appearance of *T. thynnus* larvae from the Atlantic and Indo-Pacific Oceans. The identification of *T. tonggol* and *T. maccoyii* larvae was not conclusive. The larvae of *T. atlanticus* required further study.

The workshop further concurred that juveniles (13-200 mm SL) of several species of *Thunnus* may be separated by internal and external characters: *T. atlanticus* by vertebral count, *T. alalunga* by shape of first elongate haemal spine and arrangement of pterygiophores of the second dorsal fin relative to two adjacent neural spines, and *T. thynnus* by configuration of lateral line and arrangement of pterygiophores of the second dorsal fin; and that juveniles of *T. obesus* and *T. albacares* may be separated from the previous three species by arrangement of pterygiophores of the second dorsal fin, but not from each other.

The proper identification of larval tunas has been a perplexing and difficult problem for many years. Although progress in the past two decades has resulted in agreement on the identification of larvae of a number of species (*Katsuwonus pelamis, Euthynnus alletteratus, E. affinis, E. lineatus, Thunnus thynnus, T. obesus,* and *Auxis* spp.), there is still some disagreement and confusion on the identity and description of *T. alalunga* and *T. albacares*. At the present time there are two different descriptions given for *T. alalunga* (Matsumoto, 1962; Yabe and Ueyanagi, 1962). The identity of other tunas, such as *T. tonggol, T. maccoyii,* and *T. atlanticus,* has yet to be confirmed or resolved.

One of the chief problems in larval tuna identification is the difficulty in obtaining good series of larvae for study. Tuna larvae are seldom taken in sufficient numbers by the usual collecting methods, and individuals over 10 mm standard length (SL) are taken rather infrequently. Additionally, although the young of a number of tuna species are found together in many parts of the ocean, some species are localized in certain areas. Consequently, it is extremely difficult for workers in different parts of the world to have

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at hand a complete series of larvae of more than two to four species.

In an attempt to resolve the conflicting views on *T. alalunga* and to review the identification of larvae of other species of tunas, a Larval Tuna Identification Workshop was held at the Bureau of Commercial Fisheries (BCF) Biological Laboratory (now the National Marine Fisheries Service, Southwest Fisheries Center), Honolulu, Hawaii, on March 2-6, 1970. The workshop also afforded an opportunity to workers specializing on larval tuna identification to assemble specimens of the various species of tunas and to examine these together. The procedure followed at the workshop was (1) to summarize the status of larval tuna identification to date by species and (2) to evaluate the identifying characters by examining larval specimens. As time permitted, the status of juvenile tuna identification was also examined.

The participants included:

Mr. Walter M. Matsumoto, Convenor
Dr. Elbert H. Ahlstrom, Advisor
Dr. Santhappan Jones
Mr. Witold L. Klawe
Dr. William J. Richards
Dr. Shoji Ueyanagi

Dr. Jean-Yves Le Gall of the Centre Océanologique de Bretagne, Brest, France, attended the workshop as an observer.

The sessions were conducted informally with a summary of the present status of larval tuna identification, including recent developments, followed by evaluation of the various characters that could be relied upon for positive identification. Most of the sessions were devoted to direct examination of larval specimens of the various species and discussions of unpublished data offered by participants.

This report summarizes the proceedings and results of the workshop.

RECENT DEVELOPMENTS IN THE IDENTITY OF *Thunnus alalunga*

Two differing versions of the identity and description of *T. alalunga* had arisen from reliance on black pigmentation in different parts of the body. Matsumoto (1962) relied upon black pigmentation on the dorsal and ventral edges of the trunk forward of the caudal fin base, whereas Yabe and Ueyanagi (1962) relied upon black pigmentation on the tips of the upper and lower jaws and the absence of pigmentation on the trunk.

The lack of sufficient larvae fitting Matsumoto's description from areas presumed to be spawning grounds on the basis of gonad studies casts some doubt on his identification. On the other hand, good correspondence in the occurrence of larvae fitting Yabe and Ueyanagi's description with catches of adult *T. alalunga* in various areas in the Pacific seemed to support the latter identification. A study of red pigment patterns in larvae prior to preservation (Ueyanagi, 1966) reinforced Yabe and Ueyanagi's identification and description. Additional observations on red pigmentation by Matsumoto (see later discussion) confirmed Ueyanagi's results and also provided more data to enhance the reliability of red pigmentation as a supplementary character for identifying *T. alalunga*.

IDENTIFICATION OF TUNA LARVAE

With the problem of differences in the identity and description of *T. alalunga* larvae fairly well settled at the outset, there remained the tasks of evaluating the various identifying characters, not only for this species but for other tunas as well, and of describing the species at various size categories.

DEFINITION OF LARVA

In tunas, as in many other fish, it is difficult to clearly separate the larval from the juvenile stages because there is no marked metamorphosis and the usual adult characters used for species identification develop gradually and separately. It is generally accepted among workers in larval tunas that the larval stage ends when the larva has developed the full complement of spines and rays in all the fins, all the vertebrae have ossified, and the anal opening has moved back near the origin of the anal fin. For nearly all tuna species, these developments occur when the larva has attained 10 to 13 mm SL. We use this as our definition, also.

EVALUATION OF CHARACTERS

In identifying fish larvae collected in plankton nets, the easiest and perhaps the only recourse is to identify the largest stage and work down to the smallest. Unfortunately, very few tuna larvae above 9 mm SL are taken in plankton net tows so that this process cannot be followed at all times and identification, therefore, must depend upon those nonadult characters that are the most distinctive and consistent throughout the size range.

Characters that have been used in the past were reviewed and evaluated. A résumé of the usefulness of the various characters follows.

Meristic

The number of myomeres is useful in separating *Katsuwonus pelamis* (42-43) and *Euthynnus lineatus* (38-39) from other tunas, including other species of *Euthynnus*, all of which have similar numbers of myomeres (40-41). The number of fin rays and spines are not useful for separation of *Thunnus* because all species are similar in this respect.

Morphological

Shape of first dorsal fin, when completely formed, is useful to distinguish late larval stages of *K. pelamis*, *Euthynnus*, and *Auxis* from those of *Thunnus*. Preopercular spines are unreliable because they undergo rapid growth changes and position of eye relative to longitudinal axis of body needs to be determined more accurately. Distribution (number and position) of pterygiophores in the second dorsal fin in relation to neural spines is useful in separating several *Thunnus* species, but only after these bones have ossified in larvae longer than 10 mm SL. Other characters of the axial skeleton useful in identification, such as the position of the first haemal arch and the position of the zygapophyses on the vertebrae, also form late.

Measurements

Morphometrics have not been used extensively to date, although there may be some with good possibilities, such as the relations of body depth to standard length, snout length to head length, and snout length to orbit diameter. Some of the reasons for not using measurement data are that the larvae not only shrink in preservatives, but the degree of shrinkage varies in different preservatives and with duration of preservation; the distortion of the body at the time of fixing cannot be controlled; and, more important, there are too few larvae in undistorted condition for reliable measurements. Added to these are other sources of variability such as rapid changes in body parts due to growth, changes which often occur in spurts, and distension of the abdomen, as well as stretching of the body at each feeding.

Pigmentation

For the most part black pigment patterns have been the most widely used and accepted character in identifying tuna larvae. There are variations and changes in black pigment patterns on tuna larvae due to growth, but in certain areas of the body these patterns have been found to be consistent enough for identification purposes. This is particularly true of pigment patterns on the first dorsal fin, posterior half of the trunk, forebrain, and tips of both jaws. The larval size at which black pigment cells appear in certain areas of the body, especially at the upper and lower jaw tips, may be useful in separating *T. albacares* from *T. alalunga*. Red pigment patterns, although not species specific, have been useful in confirming the identification of *T. alalunga* when used in conjunction with black pigment patterns.

Of all the characters reviewed and examined, pigment patterns, both black and red, were considered to be the most reliable for identification of the larval stages, despite their known variability, when supplemented by the use of certain morphological characters such as the distribution of pterygiophores in the second dorsal fin and characteristics of the vertebral column, whenever these are developed.

VERIFICATION OF RED PIGMENTATION

Ueyanagi (1966) reported on the usefulness of red pigmentation in identifying tuna larvae. Up to then identification of tuna larvae by pigmentation had been based on black pigment only.

Ueyanagi examined 350 larvae and concluded that *T. albacares* and *T. alalunga*, which are difficult to identify by the usual diagnostic characters, could be distinguished by differences in red pigment patterns: larvae of *T. alalunga* consistently had more red pigment spots on the dorsal and ventral edges of the body and along the mid-lateral line forward of the caudal peduncle than larvae of *T. albacares;* red pigment patterns in larvae of *T. thynnus* and *T. obesus* were intermediate between those of *T. alalunga* and *T. albacares;* the red pigment pattern in *Allothunnus fallai* was similar to that in *Thunnus;* and the pattern in *K. pelamis* resembled that in *Auxis* spp. and *E. affinis* but differed from that in *Thunnus*.

To confirm these results and to provide additional information on red pigmentation in tuna larvae, the results of observations made on 432 larvae taken in Hawaiian waters during August and September 1967 were presented. Tables 1 and 2 give the number of red pigment cells along the dorsal, ventral, and lateral lines on the posterior half of the trunk and a summary of the number of larvae examined, the number of larvae observed with red pigmentation, and the mean numbers of red pigment cells at the three sites. In Table 2, the number of red pigment cells observed most frequently are given in bold face type and those observed occasionally or seldom are enclosed in parentheses.

The pigment patterns agreed generally with those reported by Ueyanagi for the species listed in the tables. Differences in the patterns were noticeable mainly in the dorsal edge of the trunk and, to a lesser extent, in the mid-lateral line. There was no significant difference in the number of pigment cells between the left and right sides of the body.

The appearance and extent of red pigment cells varied in larvae taken in night and day tows. In larvae taken at night the pigment cells were numerous, distinct, and brightly colored, whereas in larvae taken during the day the pigment cells were faintly colored, often not visible, and in many instances the pigment spots were united, forming single continuous lines. Of the species taken in both day and night tows (*T. albacares, T. obesus,* and *K. pelamis*), red pigmentation was not visible in 41.5% of the larvae taken during the day, compared with only 3.6% of the larvae taken at night. Thus, observations of red pigment cells must be made largely on larvae taken at night to reduce the effects of diel variations.

Despite the variations, red pigmentation is a useful supplementary character to either separate certain species or verify the identification made on the basis of other characters. That the red pigment pattern is not species specific is clearly seen in the similarity among *K. pelamis, Auxis* spp., and *E. affinis* and between *T. obesus* and *T. albacares;* however, it is useful in separating *T. alalunga* from the other kinds of *Thunnus*.

EXAMINATION AND DISCUSSION OF SPECIES

Thunnus alalunga and *T. albacares*

Larvae of these two species were examined together because they are the only species lacking black pigment cells on the trunk, exclusive of the caudal fin and abdomen (Yabe and Ueyanagi, 1962). Characters, including some that have not been used in the past, for separating the two species are summarized in Table 3. The larval stage was divided into two size categories, small larvae less than 10 mm SL and larger larvae 10 to 13 mm SL, because the characters used in differentiating small larvae became ineffective or obscured with growth. As mentioned earlier, pigmentation, particularly the presence of black pigment cells at the tips of the upper and lower jaws and the amount of red pigment cells on the trunk, was the most reliable character in separating larvae of the two species.

In small larvae, black pigment cells on the lower jaw tip were first observed in larvae of *T. albacares* about 4.5 to 6.0 mm SL, and often as small as 3.8 mm SL; those on the upper jaw tip were first observed in larvae about 7.0 mm SL (Figures 1 and 2, reproduced from Matsumoto, 1958[7]). In *T. alalunga* these pigment cells were

[7] The difference in developmental stages per given size in the figures by Matsumoto (1958) and Ueyanagi (1969) is due to method of preservation: Matsumoto's figures are of larvae preserved in 10% Formalin; Ueyanagi's figures are of larvae preserved in 70% alcohol.

TABLE 1.—Frequency of red pigment cells in larval tunas from Hawaiian waters, August-September 1967.

Part of body	No. of pigment cells	*Thunnus albacares*			*Thunnus obesus*			*Thunnus alalunga*			*Katsuwonus pelamis*			*Auxis* spp.			*Euthynnus affinis*		
		Left side	Right side	Percent occurrence[1]	Left side	Right side	Percent occurrence[1]	Left side	Right side	Percent occurrence[1]	Left side	Right side	Percent occurrence[1]	Left side	Right side	Percent occurrence[1]	Left side	Right side	Percent occurrence[1]
Dorsal edge trunk	0	56	52	51.9	26	26	57.7	--	--	--	86	87	99.4	49	20	94.5	8	7	100.0
	1	42	32	35.6	16	18	37.7	--	--	--	--	--	--	2	2	5.5	--	--	--
	2	10	9	9.1	4	--	4.4	3	3	46.1	1	1	0.6	--	--	--	--	--	--
	3	4	2	2.9	--	--	--	3	3	46.1	--	--	--	--	--	--	--	--	--
	4	--	1	0.5	--	--	--	1	--	7.7	--	--	--	--	--	--	--	--	--
Total		112	96	--	46	44	--	7	6	--	87	88	--	51	22	--	8	7	--
Mid-lateral line trunk	0	4	9	6.3	11	8	21.6	--	--	--	85	86	97.7	35	16	70.0	6	7	86.7
	1	12	11	11.2	6	8	15.9	--	--	--	1	--	0.6	13	5	24.6	--	--	--
	2	45	34	38.3	11	13	27.3	--	1	7.7	1	1	1.1	2	1	4.1	1	--	6.7
	3	31	24	26.7	10	8	20.4	3	2	38.4	--	1	0.6	1	--	1.4	1	--	6.7
	4	14	14	13.6	7	5	13.6	3	3	46.1	--	--	--	--	--	--	--	--	--
	5	4	3	3.4	--	1	1.1	1	--	7.7	--	--	--	--	--	--	--	--	--
	6	1	--	0.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total		111	95	--	45	43	--	7	6	--	87	88	--	51	22	--	8	7	--
Ventral edge trunk	0	1	--	0.5	--	1	1.2	--	--	--	1	--	0.6	--	--	--	--	--	--
	1	--	--	--	2	--	2.4	--	--	--	2	2	2.3	--	--	--	--	--	--
	2	1	--	0.5	1	--	1.2	--	--	--	3	5	4.6	4	2	8.2	--	--	--
	3	2	7	4.6	3	4	8.6	--	--	--	5	5	5.7	4	--	5.5	--	--	--
	4	6	9	7.7	7	5	14.8	--	--	--	6	4	5.7	3	1	5.5	--	1	6.7
	5	13	16	14.9	12	10	27.1	1	--	7.7	9	12	12.0	2	5	9.6	1	3	26.7
	6	19	14	17.0	8	10	22.1	2	--	15.4	8	8	9.0	3	1	5.5	3	--	20.0
	7	22	14	18.5	5	4	11.1	1	3	30.8	17	8	14.3	5	2	9.6	--	1	6.7
	8	14	12	13.4	4	3	8.6	2	--	15.4	7	12	10.8	10	3	17.8	1	2	20.0
	9	6	7	6.7	--	1	1.2	--	1	7.7	12	10	12.6	3	1	5.5	2	--	13.3
	10	7	5	6.2	--	--	--	--	1	7.7	6	10	9.1	8	4	16.4	1	--	6.7
	11	3	2	2.6	--	--	--	--	--	--	6	5	6.3	1	1	2.7	--	--	--
	12	3	1	2.1	--	1	1.2	1	1	15.4	1	4	3.9	6	1	9.6	--	--	--
	13	1	--	0.5	--	--	--	--	--	--	--	1	0.6	--	1	1.4	--	--	--
	14	2	1	1.5	--	--	--	--	--	--	2	1	1.7	2	--	2.7	--	--	--
	15	--	2	1.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	16	1	--	0.5	--	--	--	--	--	--	1	1	1.1	--	--	--	--	--	--
	17	--	--	--	--	--	--	--	--	--	1	--	0.6	--	--	--	--	--	--
	18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	20	1	1	1.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total		103	91	--	42	39	--	7	6	--	87	88	--	51	22	--	8	7	--

[1] Percent occurrence refers to left and right sides combined.

TABLE 2.—Summary of red pigment cells in larval tunas from Hawaiian waters, August-September 1967.

Species	Number larvae examined	Larvae with red pigment	Red pigment cells on posterior half of trunk					
			Dorsal edge		Mid-lateral line		Ventral edge	
			Number[1]	Mean	Number[1]	Mean	Number[1]	Mean
Thunnus albacares	130	112	**0**, 1, 2, (3)	0.6	(0), 1, **2**, 3, 4, (5)	2.4	3-12	7.0
Thunnus obesus	63	47	**0**, 1, (2)	0.5	0, 1, **2**, 3, 4	1.9	1-8	5.3
Thunnus alalunga	6	6	**2, 3,** (4)	2.6	(2), 3, **4**, (5)	3.5	5-12	8.0
Katsuwonus pelamis	138	88	**0**	0.0	**0**	0.0	1-12	7.2
Auxis spp.	72	51	**0**, (1)	0.0	**0**, 1, (2)	0.4	2-14	7.6
Euthynnus affinis	23	8	**0**	0.0	**0**, (2), (3)	0.3	4-10	6.7
Total	432	312						

[1] Less than 2% occurrence omitted.

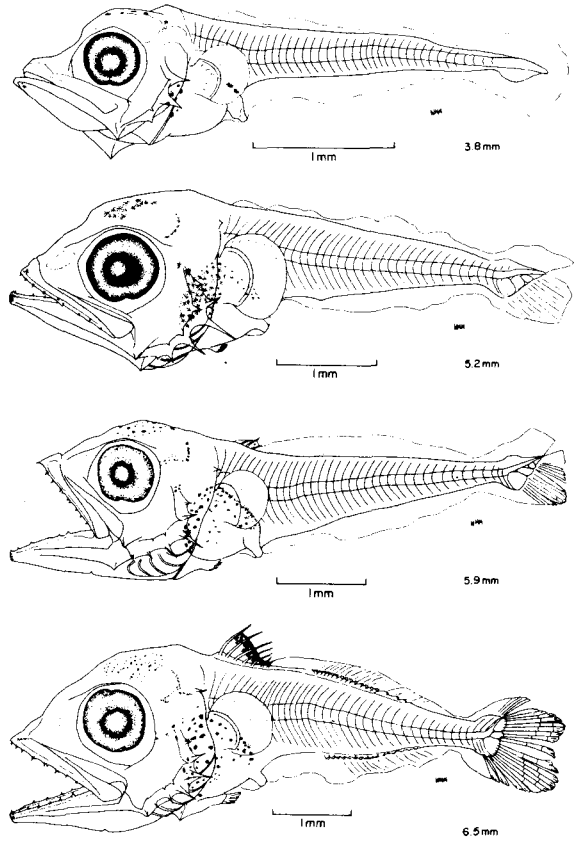

FIGURE 1.—Larval stages of *Thunnus albacares*, I. (From Matsumoto, 1958. Lengths have been converted from total to standard.)

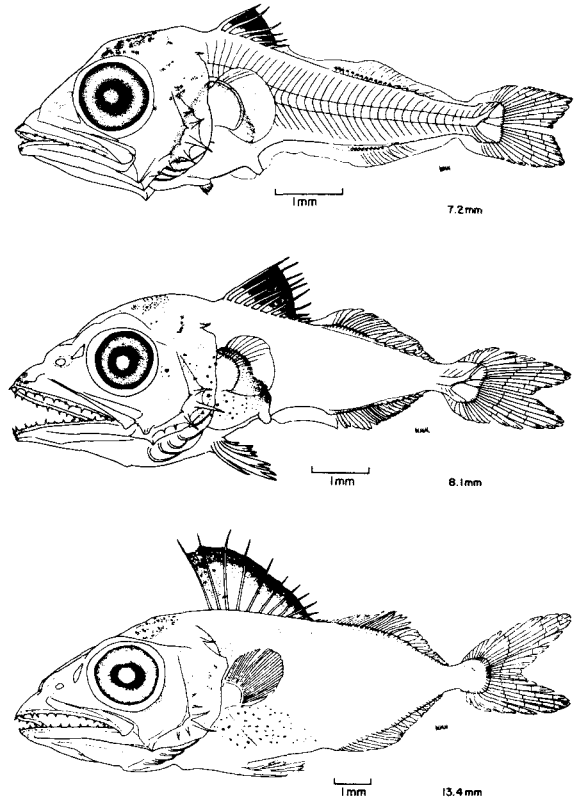

FIGURE 2.—Larval stages of *Thunnus albacares*, II. (From Matsumoto, 1958. Lengths have been converted from total to standard.)

first observed on the upper jaw tip in larvae about 5.0 mm SL and on the lower jaw tip at about 9.0 to 10.0 mm SL (Figures 3 and 4, reproduced from Ueyanagi, 1969). Consequently, all larvae between 4.5 and 7.0 mm SL having black pigment cells only on the lower jaw tip, and larvae between 7.0 and 9.0 mm SL having black pigment cells on the tips of both jaws were considered as *T. albacares*. All larvae between 5.0 and 9.0 mm SL having black pigment cells

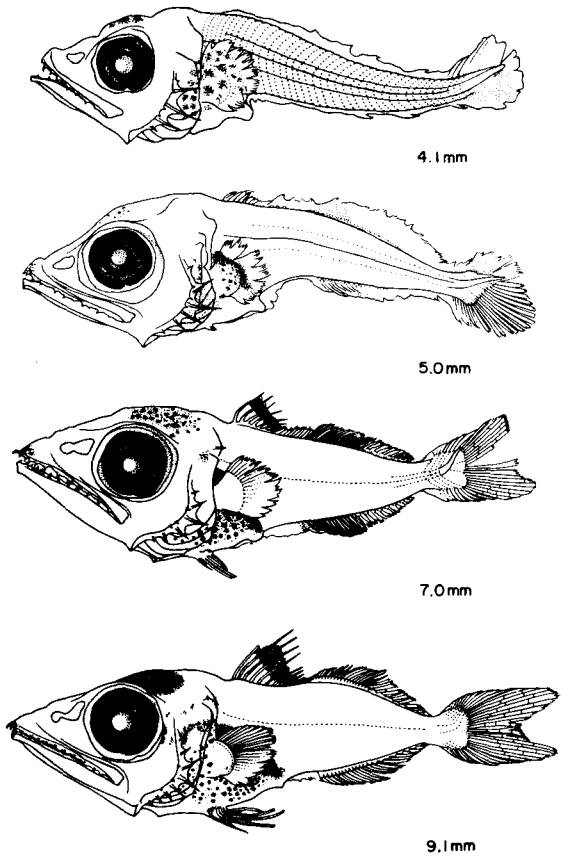

FIGURE 3.—Larval stages of *Thunnus alalunga*, I. (From Ueyanagi, 1969. Lengths have been converted from total to standard.)

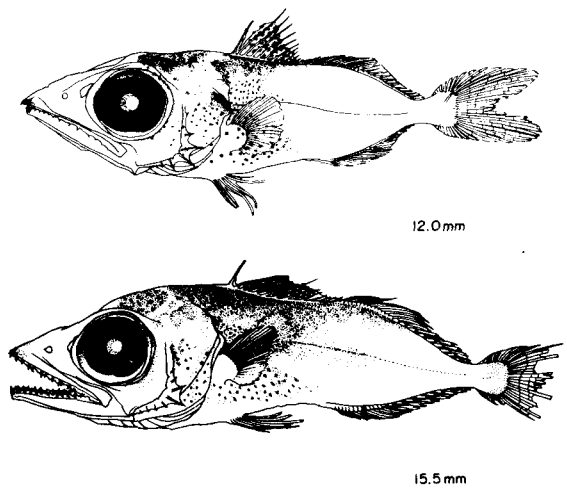

FIGURE 4.—Larval stages of *Thunnus alalunga*, II. (From Ueyanagi, 1969. Lengths have been converted from total to standard.)

only on the upper jaw tip were considered as *T. alalunga*. Larvae of the two species from 9.0 to 10.8 mm SL were separated by the position of black pigment cells on the lower jaw tip: in *T. albacares* the pigment cells were located on the inner, and sometimes outer, margins in larvae up to 10.8 mm SL, but in *T. alalunga* they were found only on the outer margin. It is suspected that the black pigment cells on the inner margin of the jaw in *T. albacares* migrate to the outer margin with further growth of the larvae.

Red pigmentation was accepted as a good supplementary character for separating *T. albacares* from *T. alalunga* (Tables 1 and 2). The distinctive patterns were located along the dorsal margin of the trunk from about the midpoint of the second dorsal fin base to the caudal peduncle. In *T. albacares* there was usually none or one red pigment cell at the caudal peduncle. Two pigment cells occurred seldom and three or four pigment cells occurred only rarely. Generally, these pigment cells were clustered at the caudal peduncle region. In *T. alalunga* there were usually two or three pigment cells, sometimes as many as four. Unlike those in *T. albacares*, these pigment cells were well spaced, extending forward to the middle of the second dorsal fin base. Only minor differences were noted in the red pigment cells along the mid-lateral line.

In larger larvae (10-13 mm SL) differences in the two species were noted in the distribution of pterygiophores of the second dorsal fin on cleared and stained specimens (Table 3). In *T. albacares* the two successive single pterygiophores between two adjoining neural spines occurred at the posterior end, whereas in *T. alalunga* they were at the anterior end. Additionally, the first haemal arch was on the 11th vertebra in *T. albacares* and on the 10th vertebra in *T. alalunga*.

TABLE 3.—Characters to separate larvae of *Thunnus albacares* and *Thunnus alalunga*.

Characters	*T. albacares*	*T. alalunga*
Small larvae (4-10 mm SL):		
Black pigmentation:		
Upper jaw	Appears at about 5.8 mm SL, mostly after 6.0 mm SL	Appears at about 5.0 mm SL
Lower jaw	Appears at 4.5-6.0 mm SL	Appears at 9-10 mm SL
	At tip on inner edge; migrate to outer edge with further growth	At tip on outer edge
Red pigmentation:		
Dorsal edge body, postanus	**0**, 1, 2, (3) [mean = 0.6]; near caudal peduncle	**2**, **3**, (4) [mean = 2.6] from peduncle to mid-second dorsal fin base
Lateral line, postanus	(0), 1, **2**, 3, 4, (5) [mean = 2.4]	(2), **3**, **4**, (5) [mean = 3.5]
Ventral edge body, postanus	3-12 [mean = 7.0]	5-12 [mean = 8.0]
Large larvae (>10 mm SL):		
Array of $^1D_2$ pterygiophores between two adjacent neural spines	1, 2, 2, 2, 3, 2, 1, 1	1, 1, 2, 2, 2, 3, 2, 1
Position of first haemal arch (vertebra number)	11th	10th

[1] D_2 refers to second dorsal fin.

Other *Thunnus* species

These species, which include *T. thynnus* (*T. thynnus thynnus* of Atlantic and *T. thynnus orientalis* of Pacific), *T. tonggol*, *T. maccoyii*, and *T. obesus*, have been identified mainly by black pigmentation on the trunk other than that over the abdominal wall.

In small *T. thynnus* of both Atlantic and Pacific Oceans (larvae between 3 and 10 mm SL), one or two large black pigment cells are present on the dorsal edge of the trunk between the second dorsal and caudal fins (Table 4, Figures 5 and 6), the anterior one usually being the larger. There may also be one to four black pigment cells on the ventral edge of the trunk between the anus and the caudal fin. Black pigmentation in *T. thynnus* from both oceans agrees quite well, except that in 5 out of 10 Atlantic specimens one or two tiny black pigment cells were noted along the mid-lateral line of the body near the pectoral fin, and in two instances a single tiny black pigment cell was found on the mid-lateral line beneath the posterior end of the second dorsal fin. These pigment cells were not considered reliable for identification purposes.

Observation of red pigmentation on larvae of Atlantic and Pacific *T. thynnus* is incomplete. Only one Atlantic *T. thynnus* larvae was examined for this character, but unfortunately the specimen was taken in a day tow so that the pigmentation appeared as a continuous streak on both the dorsal and ventral edges of the trunk as well as on the ventral surface of the lower jaw. In Pacific *T. thynnus* there were one to five red pigment cells, usually three, on the dorsal edge of the trunk. The number of red pigment cells on the mid-lateral line and ventral edge of the trunk has not been recorded, but according to the lllustration by Ueyanagi (1966), the pigment pattern may be similar to that of *T. obesus*. On the basis of black and red pigmentation, the Atlantic and Pacific *T. thynnus* were not separable.

The identification of *T. tonggol*, based on size series of 4.2 to 7.3 mm, has yet to be confirmed. Following the description of the species by Matsumoto (1962), larvae similar to these having the anteriormost black pigment cell on the dorsal edge of the body ahead of the second dorsal fin origin have been found in 1963 in the mid-South Atlantic Ocean near Ascension Island. Confirmation of the species description requires the finding of adults within this area and the finding of additional larvae to extend the identified size range.

The identification of *T. maccoyii*, which was first described as having black pigment pattern similar to that of *T. thynnus* (Yabe, Ueyanagi, and Watanabe, 1966) and later as having the black pigment cells on the dorsal edge of the trunk reduced to pinpoints (Ueyanagi, 1969), also needs verification (see discussion on *T. thynnus*). The correspondence of published descriptions based on eight specimens and observations of larvae identified as this species were not conclusive.

T. obesus was easily separated from *T. thynnus* by the absence of black pigmentation on the bases of the anterior dorsal finlets. Sometimes a single small black pigment cell was present along the ventral edge of the trunk near the caudal peduncle, but more often one to three pig-

TABLE 4.—Characters used to separate larvae of *Thunnus* species having black pigmentation on trunk.

Characters	*Thunnus thynnus* (Atlantic)	*Thunnus thynnus* (Pacific)	*Thunnus tonggol*	*Thunnus maccoyii*	*Thunnus obesus*
Small larvae (3-10 mm SL):					
Number of black pigment cells:					
Upper jaw tip	No observation	Appears above 6 mm SL	No observation	Appears above 5 mm SL	Few spots above 5 mm SL
Lower jaw tip	2 on inner edge	2 on inner edge above 4 mm SL	No observation	Appears above 4 mm SL	0-2 on inner edge below 4 mm SL
Dorsal edge trunk	1 or 2	1 or 2	1, 2, or more	1 or 2, very small	None
Lateral line	0-2 near mid-trunk	None	None	0 or 1 near mid-trunk	None
Ventral edge trunk	1-4	2 or more	2 or more	1-3	1 or more
Number of red pigment cells:					
Dorsal edge trunk	Streak on caudal peduncle[1]	1-5, mostly 3	No observation	No observation	0, 1, (2)
Lateral line	Indistinct[1]	Number not available	No observation	No observation	0, 1, 2, 3, 4
Ventral edge trunk	Streak anus to caudal peduncle[1]	Number not available	No observation	No observation	1-8 [mean = 5.3]
Lower jaw ventral view	Streak along margin anterior half of jaw and midline[1]	2 well spaced on anterior half	No observation	No observation	1 on each side near tip
Large larvae (>10 mm SL):					
Array of $^2D_2$ pterygiophores between two adjacent neural spines	1, 2, 2, 3, 2, 2, 1, 1	No observation	No observation	No observation	1, 2, 2, 2, 3, 2, 1, 1

[1] Only one larva taken in a day tow was examined.
[2] D_2 refers to second dorsal fin.

ment cells were present along the base of the posterior half of the anal fin. Red pigmentation did not differ from that in *T. albacares*.

In larger larvae (10-13 mm SL) the array of pterygiophores of the second dorsal fin between two adjacent neural spines was sufficient to separate *T. thynnus* from *T. obesus* and both species from *T. alalunga* (Tables 2 and 3). In *T. thynnus* the greatest number of pterygiophores (3) between two adjacent neural spines appeared in the fourth position in the array, whereas in *T. obesus* and *T. alalunga* it appeared in the fifth and sixth positions, respectively. *T. obesus* was not distinguishable from *T. albacares* by this character.

The identification of *T. atlanticus* was not resolved. No larvae from the distributional range of this species (tropical western Atlantic) have been found which are distinguishable from any of the species considered above. One of us (Richards) suspects that *T. atlanticus* larvae are very similar to larvae of *T. obesus*. This suspicion is based on the great abundance of larvae resembling those of *T. obesus* in this area, particularly at times and places where *T. obesus* adults are rarely found or absent. Further studies are needed.

SUMMARY OF LARVAL IDENTIFICATION

On the basis of the examination and discussion above, the workshop agreed that:

1. The description of *T. albacares* by Matsumoto (1958) was correct (see Figures 1 and 2), but that the "appearance of black pigmentation at the tip of the lower jaw at about 4.5 mm SL" should be included.

2. The description of *T. alalunga* by Yabe and Ueyanagi (1962) and illustrations by Ueyanagi (1969) were correct (see Figures 3 and 4), but that the lower size limit should be set at about 4.5 mm SL until further studies indicate more precisely the earlier appearance of black pigmentation at the tip of the lower jaw in *T. albacares*.

3. It is not possible to separate larvae of *T. albacares* from *T. alalunga* below 4.5 mm SL, prior to the appearance of black pigment cells at the tip of the lower jaw in *T. albacares*.

4. The description of *T. thynnus* by Yabe, Ueyanagi, and Watanabe (1966) was correct

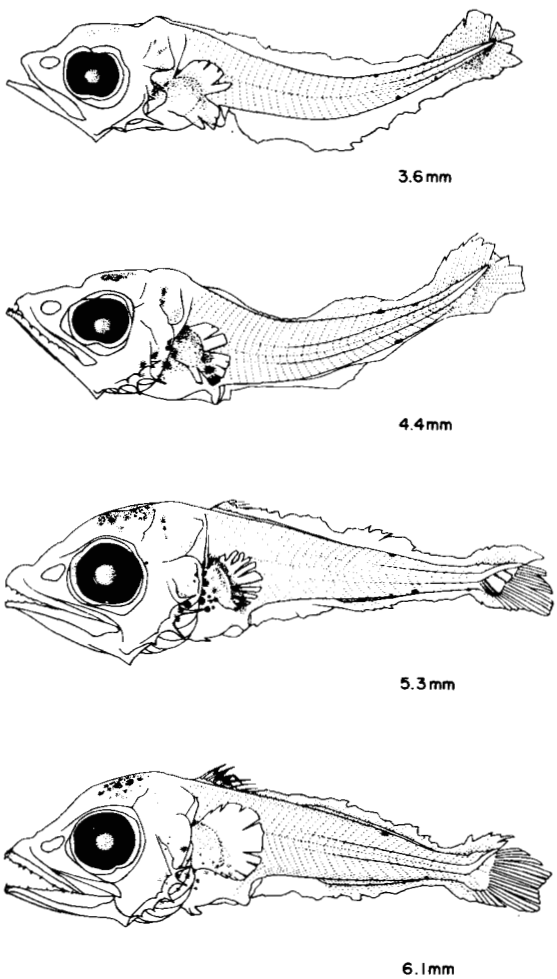

FIGURE 5.—Larval stages of *Thunnus thynnus*, I. (From Yabe, Ueyanagi, and Watanabe, 1966. Lengths have been converted from total to standard.)

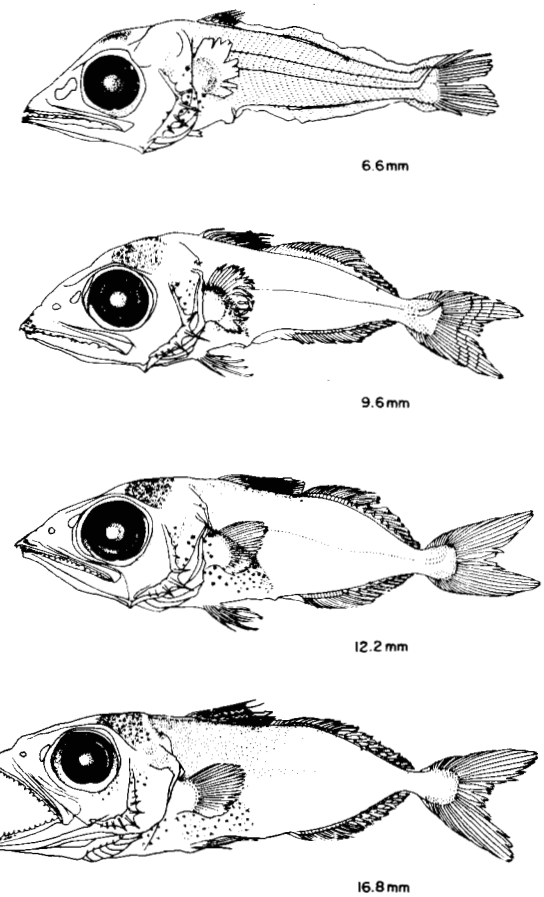

FIGURE 6.—Larval stages of *Thunnus thynnus*, II. (From Yabe, Ueyanagi, and Watanabe, 1966. Lengths have been converted from total to standard.)

(see Figures 5 and 6), and that there was no difference in *T. thynnus* from the Atlantic and Pacific Oceans.

5. The identification of *T. tonggol* was not substantiated by an adequate size series.

6. The description of *T. maccoyii,* based on tiny melanophores on the dorsal edge of the trunk, was not conclusive.

7. The description of *T. obesus* by Matsumoto (1962) was correct, though it needed to be augmented by illustrations of a complete size series.

8. The identity of *T. atlanticus* larvae is unresolved.

IDENTIFICATION OF JUVENILES

In spite of the intention of the workshop to assemble as many specimens of juvenile tunas as possible, only a few juveniles of *T. albacares* and *T. obesus,* not nearly enough to warrant their detailed examination, were available for study. The discussion on juvenile tuna identification, therefore, dealt mainly with published reports and with contributed data, resulting in a summary of identifying characters which the workshop considered useful and reliable.

Once the young tuna has acquired the full complement of spines and rays in all the fins, complete ossification of all the vertebrae, and the relocation of the anus near the origin of the anal fin, it is generally considered a juvenile of the species. Certain characters such as the full number of gill rakers, however, develop much later, when the juvenile has attained a length of 40 or 45 mm SL. If we consider juveniles to include all sizes up to the time of full gonad development signified by initial spawning, the size range of the juvenile stage would extend from about 13 mm SL to 700 mm FL (fork length) in *T. albacares* (Yuen and June, 1957) and to 860 mm FL in *T. alalunga* (Otsu and Hansen, 1962). For the purpose of clarifying species identification of the young, however, individuals beyond 200 mm SL need not be included. The term juvenile, as used here, thus refers to tunas between 13 and 200 mm SL.

EVALUATION OF CHARACTERS

The greatest difficulty in identifying juveniles of *Thunnus* is that the most useful characters are located internally. Except for the flattened first elongate haemal spine in *T. alalunga,* there is no single character that is peculiar to each of the species; but by using a combination of characters it should be possible to identify most of the other species. A summary of the most useful characters discussed is listed in Table 5. The size of juvenile at which each of the characters can be observed is listed also. Those characters whose usefulness in the early juvenile stages has not been shown conclusively are indicated by a question mark (?). The general formula of distribution of pterygiophores of the second dorsal fin has not been used before.

The counts and descriptions given for those characters listed with a question mark generally are those of the adults. These have not yet been substantiated for juveniles as well. Changes in the position of the first haemal arch with growth, for example, have been known to exist in other closely related fish such as the wahoo, *Acanthocybium solandri* (Matsumoto, 1967). This could be true of the tunas also.

Comparisons of body parts, particularly of orbit diameter, body depth at origins of the first dorsal and anal fins, preanal and postanal distances, and snout length, have not been investigated sufficiently in the past. The unavailability of specimens in sufficient numbers as well as the nonuniformity of body lengths (fork and standard) used have contributed greatly to this neglect. Acceptance of standard length as the standard measure of body length and publishing of actual measurements in the future should help in the accumulation of sufficient data for analyses. This has to be done by all workers in this field of study, since the juveniles are not easily taken in large numbers.

TABLE 5.—Characters for separating juveniles of *Thunnus* species.

Character	Useful on juveniles above	*Thunnus thynnus*	*Thunnus alalunga*	*Thunnus atlanticus*	*Thunnus obesus*	*Thunnus albacares*
First haemal arch	?	10	10	11	11	11
Ceratobranchial including angle	40 mm SL	17-20	15-16	12-13	15-16	15-16
Vertebrae	13 mm SL	18 + 21	18 + 21	19 + 20	18 + 21	18 + 21
Array of [1]D_2 pterygiophores between two adjacent neural spines	10 mm SL	1, 2, 2, 3, 2, 2, 1, 1	1, 1, 2, 2, 2, 3, 2, 1	1, 2, 2, 2, 3, 2, 1, 1	1, 2, 2, 2, 3, 2, 1, 1	1, 2, 2, 2, 3, 2, 1, 1
First prezygapophysis and position on haemal arch	?	15, 16, 17, high	15, 16, high	16, 17, low	15, 16, high	13, 14, low
Postzygapophysis near first prezygapophysis	?	Short, directed posterior	Short, directed posterior	Long, directed vertical or slightly anterior	Short, directed posterior	Long, directed vertical, some slightly anterior
First haemal spine	30 mm SL	Winglike at some stages	Extremely winglike	Winglike at some stages	--	--
Lateral line above base of pectoral fin	25 mm SL	Acute, nearly 90°	Obtuse	Obtuse	Obtuse	Obtuse

[1] D_2 refers to second dorsal fin.

DISCUSSION AND SUMMARY

T. thynnus below 25 mm SL can be separated from the other *Thunnus* species by the array of pterygiophores of the second dorsal fin, the last four positions containing 2, 2, 1, 1 pterygiophores; in *T. alalunga* the sequence is 2, 3, 2, 1, and in *T. atlanticus, T. obesus,* and *T. albacares* it is 3, 2, 1, 1. *T. thynnus* above 25 mm SL can be separated from all other *Thunnus* by the sharp angle (nearly 90°) which the lateral line follows near the base of the pectoral fin; in all other species this angle is obtuse. In juveniles above 40 to 45 mm SL, *T. thynnus* has the highest number of gill rakers on the ceratobranchial, including that at the angle (Potthoff and Richards, 1970).

T. alalunga below 30 mm SL can be separated from other *Thunnus* species by the distribution of pterygiophores of the second dorsal fin. Above 30 mm SL, *T. alalunga* is the only species whose first elongated haemal spine is flattened laterally and appears extremely winglike.

T. atlanticus as small as 13 mm SL can be separated from other *Thunnus* species by its distinctive precaudal and caudal vertebral counts. It is the only species having 19 precaudal and 20 caudal vertebrae. Above 40 to 45 mm SL, this species can be separated from the others by the low (12-13) gill raker count on the ceratobranchial (Potthoff and Richards, 1970), in addition to the vertebral formula.

T. obesus and *T. albacares* are the only two species that cannot be distinguished from each other on the basis of internal characters. Comparisons of body parts, i.e., orbit diameter, body depth or preanal and postanal distances, may have to be used.

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